Reviews

In-ground Fabric Containers as an Alternative Nursery Crop Production System

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Summary. Nursery crops have traditionally been grown in the field and harvested as balled and burlapped or bareroot plants or grown in above-ground containers. A relatively recent product, the in-ground fabric container, has allowed producers to combine advantages of field production with those of container production. The effect of these containers on plant growth, transplant establishment, plant chemical composition, and water relations appears to be species and site specific.

The fabric container is a tool that can be used to produce field-grown woody plants. Labor costs are lower at harvest with in-ground fabric containers than with balling and burlapping (B&B) by hand. Equipment costs can also be lower when trees are grown and harvested in in-ground fabric containers than when machine harvested from traditional field production. These containers have been on the market for >10 years and have received mixed reviews from producers and researchers. As with any production tool, they have advantages and disadvantages from a plant growth standpoint. Knowledge about the effect of in-ground fabric containers on various species and soil types can help producers make appropriate decisions concerning the use of these containers in their particular operation.

In-ground fabric containers, grow bags, or root bags were introduced in 1982 (Reiger and Whitcomb, 1982) and have since been marketed under several brand names. They were developed to reduce harvest costs of field-grown plants (Kurt Reiger, Root Control, Inc., Oklahoma City, Okla., personal communication). The containers have a fabric or clear polyethylene bottom stitched or glued to walls of nonwoven fabric originally created for the petroleum industry (Sallee, 1987b). Grow bags are available in several sizes. The size used for a particular crop is determined by the expected trunk diameter at harvest. Container size has been a source of discussion since grow bag sizes recommended by manufacturers for various caliper trees are generally smaller than root ball sizes for balled and burlapped plants of the same trunk diameter. The American Association of Nurserymen (AAN) recently adopted standards for grow bag sizes appropriate for various trunk diameters (AAN, 1997).

Field preparation for the in-ground grow bag system is the same as if the plants were grown under B&B culture. Dormant bareroot or container-grown plants are planted using field soil in the fabric container. Soilless media are not recommended for planting in grow bags (Cuny, 1996a). The bags are placed in the ground leaving 5.0 to 7.5 cm (2 to 3 inches) of the top extending above the soil surface. Plants in in-ground fabric containers can be planted by hand or machine (Sallee, 1987a). Some growers insert the liner and fill the grow bag before placing it into the soil, while others fill it once it is in the hole.

In essence, the plants are grown in containers in the ground. The transplants in fabric containers are often drip irrigated, but many growers use overhead irrigation. Conventional fertilization and weed control practices can be followed (Root Control, n.d.). Some fertilizer should be placed in the boundaries of the grow bag walls to ensure adequate nutrient availability to those roots confined within the bag. Care must be used in weeding not to damage the fabric bags.

At harvest, plants in grow bags are usually dug with shovels (Sallee, 1987b), but a backhoe can be used to harvest larger plants (Reiger, 1990). Some growers suggest that tree harvest using grow bags is more rapid than with B&B (Reiger and Whitcomb, 1983a) because there is no need to shape a ball.

At the time of transplanting, the fabric bag must be removed to allow the root system to grow into the soil at the new site. If the container is not removed, the root system continues to be largely confined to the volume of soil within the fabric container (Sallee, 1987b) and plant health will decline.

Grow bags continue to evolve as different designs, weaves, and fabrics are tested and marketed (Appleton, 1995a, 1995b). One grow bag is constructed of copper hydroxide-treated polypropylene that can be used in the field or in bag-in-pot production (Cuny, 1996b). Another

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in-ground fabric container is made of geotextile fabric impregnated with the herbicide trifluralin (2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine) (Appleton, 1995a, 1995b).

Advantages and disadvantages

Several advantages and disadvantages of using grow bags compared to traditional field production techniques were cited by manufacturers soon after their introduction into the market (Reiger and Whitcomb, 1983a, 1983b). Manufacturers claimed that less time and effort were spent digging while a higher proportion of the roots were retained in the root ball of plants from grow bags compared to plants dug from traditional field production (Root Control, n.d.). They said that no special machinery or skill was necessary to harvest the plants because only the small, fibrous roots penetrated the sides of the fabric containers. According to manufacturers, ≈80% of the root system was retained at harvest, so the plants could be harvested and sold yearround (Root Control, n.d.); whereas, digging plants from traditional field production was recommended only during dormancy. Sandy soils, typically unsuitable for B&B, could be used with this new system. Trees could also be held in retail areas longer without reballing (Root Control, n.d.). Manufacturers also stated that no girdling roots were produced and transplant establishment was more rapid.

Growers express mixed opinions of the grow-bag production system. Positive comments include the continuous root pruning that fabric containers provide without the growth retardation and expense associated with mechanical root pruning (James, 1988). Soil type in the growing field is less of a concern than with B&B production (Langlinais, 1988; Reese, 1988). Plants in grow bags stand upright better than those that are balled and burlapped because the bottom of the containers are flat (Langlinais, 1988). The need for heavy equipment and shipping costs is reduced (Nursery Manager, 1990). Plants in grow bags are more stable under windy conditions during production than those grown in containers on top of the ground (Langlinais, 1988). The grow-bag system can extend the harvest period because a greater proportion of the root system remains intact (Jones, 1988). Less skill is needed in workers, particularly during harvest (Nursery Manager, 1990). Early publications on grow bags indicated more rapid establishment of bag-grown nursery plants in the landscape because of increased carbohydrates and nutrients in the roots and a more fibrous root system (Appleton, 1986; Reiger and Whitcomb, 1983b; Whitcomb, 1985).

Growers suggest that the root system within in-ground fabric containers is more dense (roots/volume) (Langlinais, 1988; Reese, 1988). Langlinais (1988) and Whitcomb (1986) claim that more of the root system (75% to 85%) is maintained on a grow bag plant compared to the root system retained during harvest of balled-and-burlapped plants (calculated to be as little as 2% for large specimens) (Watson and Himelick, 1982). Gilman (1988) however showed that 18% to 20% of root length and 68% to 80% of root weight is harvested in a typical root ball of field-produced plants. This places doubt on the claim that plants in grow bags are harvested with more root system than those that are balled and burlapped.

Growers also cite disadvantages to using in-ground fabric containers compared to traditional field production methods. The initial investment in grow bags is considered a disadvantage to their use (James, 1988; Langlinais, 1988; Reese, 1988). Care must be taken in planting grow bags, since planting too deeply, air pockets, and damage to the bag render them useless in confining the root system (James, 1988; Jones, 1988). Growers have found mechanical cultivation and precise fertilizer application difficult (James, 1988). Harvesting can be a problem if roots escape from the grow bag (James, 1988). Problems in construction of some early bags have been reported.

At the time of planting into the landscape, bag removal can be difficult and time-consuming (James, 1988; Langlinais, 1988). Plants grown in in-ground fabric containers are less stable once planted and must be staked (James, 1988). Regular irrigation is critical for bag-grown transplants (Harris and Gilman, 1993). Growers indicate that the physical appearance of the grow bags on the sales yard is not desirable to the consumer (James, 1988; Reese, 1988). Other limitations of grow bags include species variability in tolerance to root restriction and a decline in tree quality when held on the sales yard (Grey, 1991; Sallee, 1987a).

Researchers found transplanting bag-grown trees much more laborious and time consuming than planting balled-and-burlapped or bareroot trees (Hensley, 1993). Root balls, especially in sandy soil, can be damaged and soil lost if the bags are not removed carefully (Hensley, 1993). Copper hydroxide-treated fabric bags are reportedly easier to remove (Cuny, 1996b); however, Ruter (1994) found removing grow bags treated with copper hydroxide difficult due to large numbers of roots growing into (but not through) the fabric.

Plant responses to grow bags

Many studies have evaluated the influence of grow bags on plant growth, root branching, plant water relations, plant nutrition, and posttransplant establishment.

PLANT GROWTH. The effect of in-ground fabric containers on plant growth varies and appears to be species and site specific. No difference in height or stem diameter growth was apparent between plants in grow bags and those grown under traditional field production for live oak (*Quercus virginiana* Mill.) (Chong et al., 1991), southern magnolia (*Magnolia grandiflora* L.), sweet gum (*Liquidambar styraciflua* L.), lacebark elm (*Ulmus parvifolia* Jacq. 'Drake'), crape myrtle (*Lagerstroemia indica* L.), 'East Palatka' holly (*Ilex* ×*attenuata* Ashe. 'East Palatka'), slash pine (*Pinus elliottii* Engelm.) (Ingram et al., 1987a, 1987b), or laurel oak (*Q. laurifolia*) (Gilman and Beeson, 1996b). The soil was a fine sand. Live oak and sweet gum trees produced by traditional field (B&B) or grow-bag methods had greater height increases and shoot fresh masses than above-ground container-produced plants (Ingram et al., 1987a, 1987b). Chong et al., (1987, 1989) grew hybrid poplar (*Populus deltoides* ×*nigra* DN 69) plants in experimental grow bags in progressively larger plastic pots with bark medium. Poplars in the grow bags were smaller than those in the same sized nursery pots without grow bags. Green ash (*Fraxinus pennsylvanica* Marsh.) also had less height and stem diameter increases when produced in grow bags in loam soil than those grown under traditional field production methods (Henderson-Cole and Hensley, 1992).

Remphrey et al. (1990) found that beginning as early as the first growing season, 'Patmore' green ash and silver maple (*Acer saccharinum* L.) trees field grown without root restriction were increasingly taller each year than the same species grown in in-ground fabric containers. No height differences between trees grown with or without root restriction were apparent for 'Dropmore' basswood (*Tilia ×flavescens* Doell. 'Dropmore') until the fourth growing season. Trees in smaller [46-cm-diameter (18-inch-diameter)] grow bags were not as tall as trees in larger [56-cm-diameter (22 inch-diameter)] bags or trees with unrestricted root systems. The difference in time before growth reduction following planting in bags was attributed to ease of transplant establishment. Green ash and silver maple are considered easy to transplant due to aggressive roots, while basswood with a less aggressive root system is considered more difficult to transplant (Remphrey et al., 1990).

Root restriction, growth, and regeneration. Early reports indicated that there may be more roots and smaller roots on plants produced in grow bags than in the rootballs of plants grown under traditional field methods (Whitcomb, 1986). Subsequent research suggests that the rooting characteristics of plants in grow bags probably depends on plant species and soil type. Root dry mass within the root ball of live oak and sweet gum was greater for in-ground fabric-container-grown plants than for plants field grown without root restriction or grown in above-ground plastic containers (Ingram et al., 1987a, 1987b). There were, however, no differences in root dry mass among these three production systems for southern magnolia, lacebark elm, crape myrtle, 'East Palatka' holly, or slash pine (Ingram et al., 1987a, 1987b). In this study, the root systems were harvested from equivalent soil volumes regardless of production method; therefore, plant responses in typical B&B production were not compared to responses in grow bags because B&B plants were not harvested with a large enough ball based on AAN standards. Gilman and Beeson (1996a) found the root spread of laurel oak outside of grow bags to be identical to the root spread on field-grown trees. They also noted that the percentage of roots outside of the grow bag was the same as that of roots outside of a ball on laurel oak and 'East Palatka' holly.

In contrast, Chong et al. (1989) found 21% fewer roots with hybrid poplar grown in grow bags filled with bark medium and then inserted in larger nursery pots and maintained above ground than with control plants grown in above-ground nursery pots without bags.

Fuller and Meadows (1987, 1988) found greater root dry masses of live oak, bald cypress (*Taxodium distichum* (L.) Rich.), red maple (*Acer rubrum* L.), and slash pine grown in silt loam soil with grow bags than without bags. In contrast, Harris and Gilman (1991) noted no difference in root dry mass of leyland cypress [*Cupressocyparis leylandii* (Dallim. & A.B. Jackson) Dallim.], laurel oak, or slash pine grown in fine sand with or without grow bags. Root density (root dry mass per unit volume) was greater in the grow bags for all species in both studies, however the root ball for balled and burlapped plants was larger at harvest.

Root systems of laurel oak in the wild have been characterized by a single taproot (Gilman et al., 1992). The same species grown under cultivation, with or without in-ground fabric containers, typically has several large roots growing straight or at a slight angle downward beneath the trunk. Gilman et al. (1992) found no difference in dry mass of roots <5 mm (0.02 inches) in diameter between field and grow bag-grown trees. Root number and cross-sectional area were comparable among wild, field grown, and bag-grown trees.

Root masses were nearly identical regardless of production method in tests using laurel oak or 'East Palatka' holly even though root balls in grow bags were half the volume of those from field-grown plants (Gilman and Beeson, 1996b). These observations suggest that plants in grow bags might transplant similarly to those that are balled and burlapped. Harris and Gilman (1993) found, however, that, without frequent irrigation after transplanting, trees from grow bags were more stressed than trees grown without root restriction.

Although the in-ground fabric containers are barriers to root growth, small roots penetrate the fabric, and those roots can get large. Roots of several species, however, have also been observed to circle within the base of grow bags (Chong et al., 1987; Cole and Hensley, 1994).

Transplant establishment. Girdling, or constricting the tree's stem, blocks translocation of carbohydrates, hormones, and other possible root-promoting factors. Chong et al. (1987) reported that grow bags girdle roots penetrating the bag. Girdling restricted the carbohydrate flow from leaves and roots of poplar to roots outside the bags and nutrient flow from roots outside the bag into the contained plant. Total root sugar content of primary roots of live oak was significantly greater for bag-grown than field-grown trees (Chong et al., 1987). Total sugar content of sweet gum roots, however, was less in bag-grown than in field-grown trees (Harris and Gilman, 1991).

Increased root dry mass in bag-grown root balls compared to field-grown trees in silt loam soil corresponded to an increase in regenerated roots 60 d after transplanting in only one of five species tested (Fuller and Meadows, 1987, 1988). Root regeneration was lower on trees grown in grow bags than those grown in field soil (Gilman, 1990). Harris and Gilman (1991) reported greater root regeneration by bag-grown slash pine and leyland cypress than for field-grown plants 10 weeks after transplanting. Laurel oak trees from grow bags regenerated the same number of roots but grew less in trunk diameter in the year after transplanting than trees transplanted from the field with a tree spade (Harris and Gilman, 1991). No differences occurred between field-grown and bag-grown trees in the number and cross-sectional areas of roots, although the bag-grown root balls were smaller (Gilman et al., 1992).

Neither caliper nor top fresh mass of 'Natchez' crape myrtle or live oak grown in sandy loam soil differed as a result of transplanting field- or grow bag-grown plants; although, height of both species was greater for transplanted field-grown plants after transplanting (Tilt et al., 1992). Root regeneration by live oak, but not crape myrtle, was enhanced in plants produced in bags. July-transplanted live oak produced in bags survived, whereas traditional field-grown trees did not (Tilt et al., 1992).

Grow bags do not promote growth of green ash after transplanting. There were no differences in average tree height, caliper, or harvested masses of roots between grow bag-grown, balled-and-burlapped, or bare root green ash (Hensley, 1993). Gilman and Beeson (1996a) found that trunk growth rates of transplanted laurel oak grown in above-ground containers, in-ground fabric containers, and those balled and burlapped were similar and matched or exceeded pretransplant growth 7 months after planting. Shoot growth of field-grown trees was greater than for the other two treatments in the first year.

PLANT NUTRITION. Chemical composition also differs between trees grown in grow bags and those grown without root restriction (Chong et al., 1987, 1989). Leaf N, K, and soluble sugar concentrations were greater in poplar trees growing in grow bags than in plants without root restriction. In contrast, leaf P content and starch concentration were not affected by root restriction (Chong et al., 1989). No differences in leaf nutrient or carbohydrate concentrations occurred in littleleaf linden (*Tilia cordata* Mill. 'Olympic'), Norway maple (*Acer platanoides* L.), green ash, silver maple, or honey locust (*Gleditsia triacanthos* var. *inermis* Willd. 'Skyline') during the first year in bag-grown or control plants (Chong et al., 1991). After 2 years, leaf N and Ca were lower in the grow-bag treatment and leaf P and K decreased after 3 years in these same species with grow bags compared to controls.

Ingram et al. (1987b) found a higher carbohydrate concentration in primary roots of live oak and southern magnolia grown in grow bags than in those without root restriction. Root N, P, and K concentrations were greater and starch concentration was lower in root-restricted poplars than in controls (Chong et al., 1987).

Since roots swell just inside and outside the fabric container, some researchers hypothesized a girdling that restricted carbohydrate flow to the roots outside the grow bag and flow of nutrients from the soil through the root system. This constriction would lead to the observed greater concentration of carbohydrates and lower concentration of nutrients in roots inside compared to those outside the grow bags (Chong et al., 1987).

WATER RELATIONS. Water relations during production of trees in in-ground fabric containers is probably intermediate between conventional field and above-ground container production. Restricting the root system during production with grow bags limits the volume of soil the tree can exploit for water. A tree grown in a grow bag requires the same amount of water as one conventionally grown to achieve the same top growth. The tree in the grow bag, however, draws water from a smaller soil volume that is depleted more rapidly than trees grown without root restriction. This suggests more frequent water stress for trees grown in grow bags without irrigation (Kjelgren et al., 1994); however, further research is needed to confirm this assumption. Without irrigation, trees grown in grow bags are subject to greater water stress than with irrigation (Gilman et al., 1994; Kjelgren et al., 1994). Trees in grow bags would likely need to be irrigated more frequently than conventionally grown trees due to a smaller rooting volume. Under drip irrigation, particularly in sandy soils, wetting an area twice that of the bag appears to aid plant growth (Gilman et al., 1994).

Once transplanted into the landscape, the same concerns about limited rooting volume must be considered. With routine irrigation trees grown in fabric bags establish as rapidly, as measured by changes in diurnal water potential, as those conventionally grown in field soil (Beeson and Gilman, 1992; Gilman and Beeson, 1996a). The smaller root ball recommended for bag-grown trees limits rooting volume and the amount of soil water that can be exploited after transplanting; thus, trees are more likely to run out of water. Harris and Gilman (1993) found that holly after being transplanted from grow bags had more negative predawn water potentials and lower photosynthesis than either container-grown or field-grown plants during a drying cycle. Because the bag-grown plants had root surface areas similar to conventionally grown plants, they speculated that bag-grown trees were more stressed because the roots were confined to half the soil volume.

Truncated rooting volumes as a result of production in in-ground fabric containers limits the amount of water that a tree can exploit. In plastic container production, plants grown for maximum leaf area with roots in a confined volume deplete water very rapidly. Similarly, water management of plants produced in grow bags should be monitored carefully during production and during establishment after transplanting. The smaller rooting volume with grow bags results in more rapid onset of water stress after transplanting that is best managed by applying the same amount of water as for conventionally field-grown and harvested trees, but more frequently (Harris and Gilman, 1993).

Conclusions

The in-ground fabric container is a tool used in producing field-grown nursery stock. Advantages and disadvantages of their use must be weighed before implementing them into a given production situation. Few economic studies have been conducted with the grow bags. Growers must be concerned with higher up-front costs of grow bags that may not be recovered for several years, depending on the crop cycle. Lower harvest costs and ease of harvest may offset some of the disadvantage of the initial cost.

Research has revealed a variety of plant responses to grow bags compared to other production practices. Growth of some species was not affected, while growth of other species was decreased in the presence of the grow bags compared to plants of the same species grown without root restriction. Growth affects appear to be species and site specific. Plant growth in sandy soil may differ less with or without grow bags than in heavier soils. This difference may be due in part to the difference in water-holding capacity between soil types.

At transplanting, the grow bags must be removed. Removal can be laborious, and care must be taken to avoid breaking the root ball. If the bag is successfully removed while maintaining the root ball intact, most research has shown no difference in plant establishment regardless of production method. After transplanting, however, plants grown in a grow bag require irrigation more frequently than field-grown trees.

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